intel®

INTEL® THREADING BUILDING BLOCKS (INTEL® TBB) 2017

Multi-threading and heterogeneous computing made easy with Intel TBB

What is Intel® TBB?

Intel TBB is a highly templatized C++ library designed to simplify the task of adding parallelism to your application by taking advantage of all the CPU's either on a single device or across multiple devices (heterogeneity).

Why should you use Intel® TBB?

- High Performance
- Easy to use API's
- Faster Time To Market
- Production Ready

Optimized for

Supports

Addresses

Find out more at: ***http://software.intel.com/intel-tbb***
Contact us through our forum:
http://software.intel.com/en-us/forums/intel-threading-building-blocks

How to get Intel® TBB?

Intel Parallel Studio XE
Intel System Studio
Free Tools Program
Open source site

Applications

- Animation Rendering
- Numeric weather prediction
- Oceanography & Astrophysics
- Artificial Intelligence & Automation
- Genetic Engineering
- Medical applications (Image processing, MRI reconstruction)
- Remote sensing applications
- Socio Economics
- Financial sector (stock derivative pricing, statistics)
- Bulk updating data files
- Any Big Data problems

Advantages of using Intel TBB over other threading models

- Specify tasks instead of manipulating threads. Intel® TBB maps your logical tasks onto threads with full support for nested parallelism
- Intel TBB uses proven , efficient parallel patterns.
- Intel TBB uses work stealing to support the load balance of unknown execution time for tasks. This has the advantage of low-overhead polymorphism.
- Flow graph feature in Intel TBB allows developers to easily express dependency and data flow graphs.
- Has high level parallel algorithms and concurrent containers and low level building blocks like scalable memory allocator , locks and atomic operations.

Rich Feature Set for Parallelism
Intel® Threading Building Blocks (Intel® TBB)

Parallel algorithms and data structures

Threads and synchronization

Memory allocation and task scheduling

Generic Parallel Algorithms

Efficient scalable way to exploit the power of multi-core without having to start from scratch.

Flow Graph

A set of classes to express parallelism as a graph of compute dependencies and/or data flow

Concurrent Containers

Concurrent access, and a scalable alternative to containers that are externally locked for thread-safety

Synchronization Primitives

Atomic operations, a variety of mutexes with different properties, condition variables

Task Scheduler

Sophisticated work scheduling engine that empowers parallel algorithms and the flow graph

Timers and Exceptions

Thread-safe timers and exception classes

Threads

OS API wrappers

Thread Local Storage

Efficient implementation for unlimited number of thread-local variables

Memory Allocation

Scalable memory manager and false-sharing free allocators

Features and Functions List
Intel® Threading Building Blocks (Intel® TBB)

Parallel algorithms and data structures

Threads and synchronization

Memory allocation and task scheduling

Generic Parallel Algorithms

- parallel_for
- parallel_reduce
- parallel_for_each
- parallel_do
- parallel_invoke
- parallel_sort
- parallel_deterministic_reduce
- parallel_scan
- parallel_pipeline
- pipeline

Flow Graph

- graph
- continue_node
- source_node
- function_node
- multifunction_node
- overwrite_node
- write_once_node
- limiter_node
- buffer_node
- queue_node
- priority_queue_node
- sequencer_node
- broadcast_node
- join_node
- split_node
- indexer_node

Concurrent Containers

- concurrent_unordered_map
- concurrent_unordered_multimap
- concurrent_unordered_set
- concurrent_unordered_multiset
- concurrent_hash_map
- concurrent_queue
- concurrent_bounded_queue
- concurrent_priority_queue
- concurrent_vector
- concurrent_lru_cache (preview)

Synchronization Primitives

- atomic
- mutex
- recursive_mutex
- spin_mutex
- spin_rw_mutex
- speculative_spin_mutex
- speculative_spin_rw_mutex
- queuing_mutex
- queuing_rw_mutex
- null_mutex
- null_rw_mutex
- reader_writer_lock
- critical_section
- condition_variable
- aggregator (preview)

Task Scheduler

- task
- task_group
- structured_task_group
- task_group_context
- task_scheduler_init
- task_scheduler_observer
- task_arena

Timers and Exceptions

- tick_count
- tbb_exception
- captured_exception
- movable_exception

Threads

- thread

Thread Local Storage

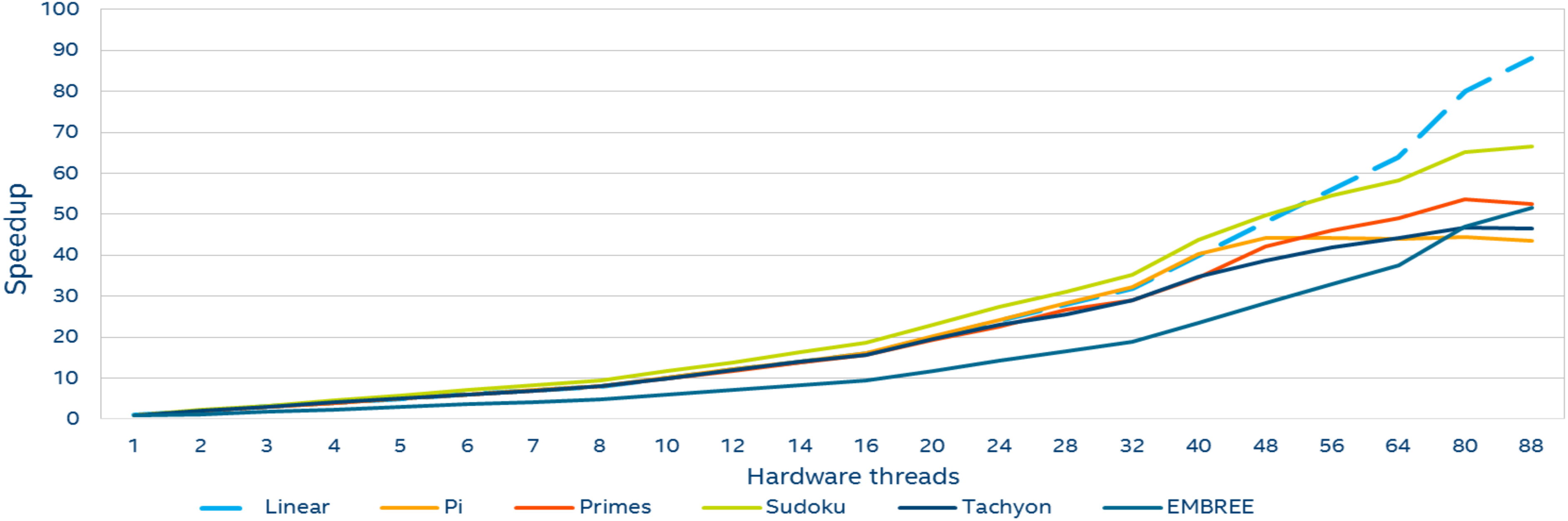
- combinable
- enumerable_thread_specific

Memory Allocation

- tbb_allocator
- scalable_allocator
- cache_aligned_allocator
- zero_allocator
- aligned_space
- memory_pool (preview)

Optimization Notice

Excellent Performance Scalability with Intel® Threading Building Blocks 2017 on Intel® Xeon® Processor



Configuration Info: Software Versions: Intel® C++ Intel® 64 Compiler, Version 17.0, Intel® Threading Building Blocks (Intel® TBB) 2017; Hardware: Intel(R) Xeon(R) CPU E5-2699 v4 @ 2.20GHz 44/88T)), 128GB Main Memory; Operating System: Red Hat Enterprise Linux Server release 7.2 (Maipo), kernel 3.10.0-327.4.5.el7.x86_64; Benchmark Source: Intel Corp. Note: sudoku, primes and tachyon are included with Intel TBB.
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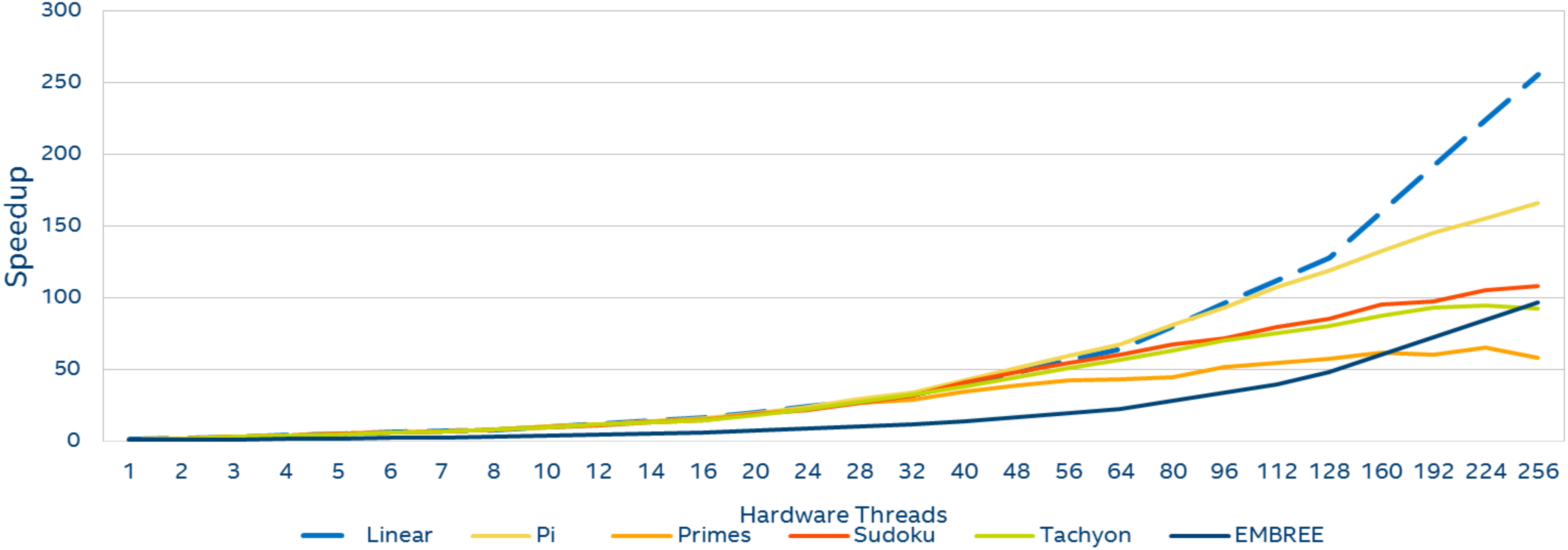
Excellent Performance Scalability with Intel® Threading Building Blocks 2017 on Intel® Xeon Phi® Processor



Configuration Info: Software Versions: Intel® C++ Intel® 64 Compiler, Version 17.0, Intel® Threading Building Blocks (Intel® TBB) 2017; Hardware: KNL (Intel(R) Xeon Phi(TM) CPU 7250 @ 1.40GHz (68C/272T)), 128GB Main Memory; Operating System: Red Hat Enterprise Linux Server release 7.2 (Maipo), kernel 3.10.0-327.13.1.el7.mpsp_1.3.2.100.x86_64; Benchmark Source: Intel Corp.Note: sudoku, primes and tachyon are included with Intel TBB.
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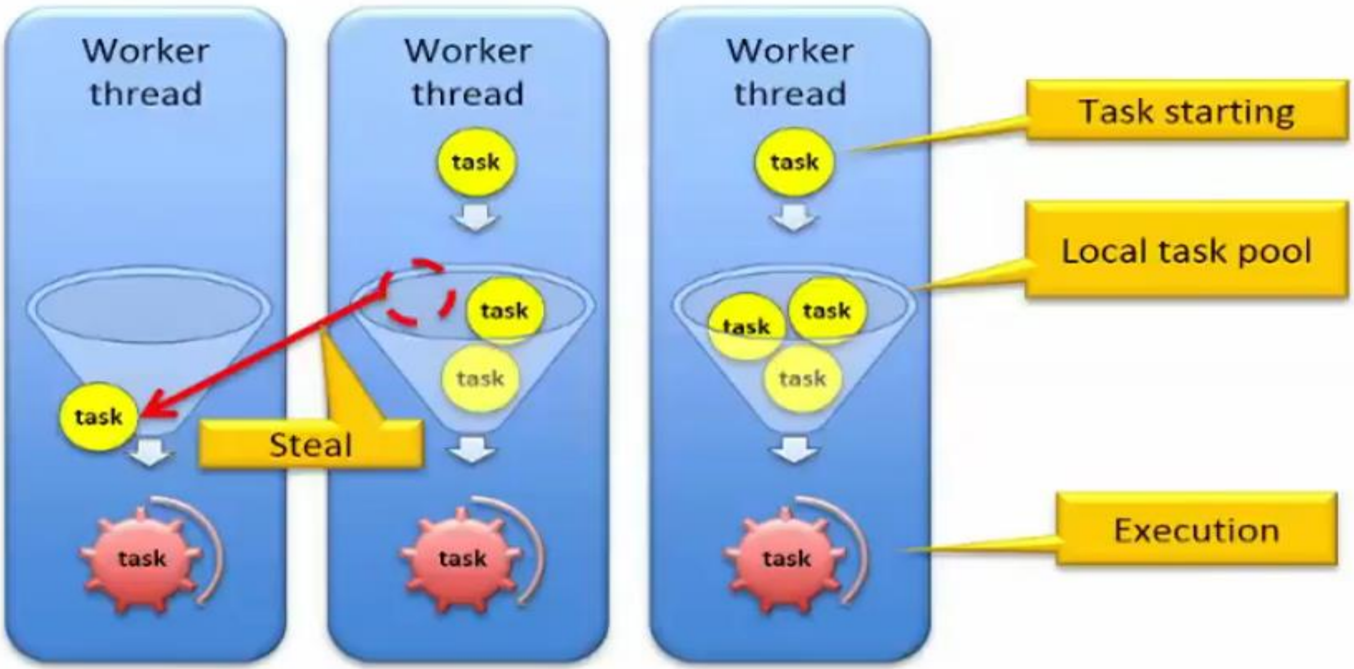
Task Execution in Intel TBB



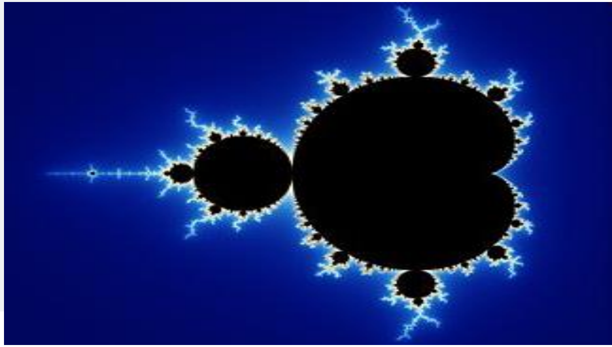
(A simplified version of the scheduler)

Generic algorithms allow reuse of proven parallel patterns

Intel® Threading Building Blocks (Intel® TBB)

Sequential version

```
int mandel(Complex c, int max_count) {
  int count = 0; Complex z = 0;
  for (int i = 0; i < max_count; i++) {
    if (abs(z) >= 2.0) break;
    z = z*z + c; count++;
  }
  return count;
}
```

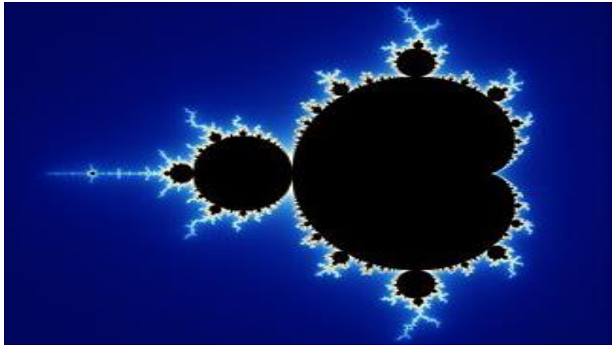


```
for (int i = 0; i < max_row; i++) {
  for (int j = 0; j < max_col; j++ ) {
    p[i][j] = mandel( Complex(scale(i), scale(j)), depth);
  }
}
```

Mandelbrot Speedup

Intel® Threading Building Blocks (Intel® TBB)

```
int mandel(Complex c, int max_count) {
  int count = 0; Complex z = 0;
  for (int i = 0; i < max_count; i++) {
    if (abs(z) >= 2.0) break;
    z = z*z + c; count++;
  }
  return count;
}
```



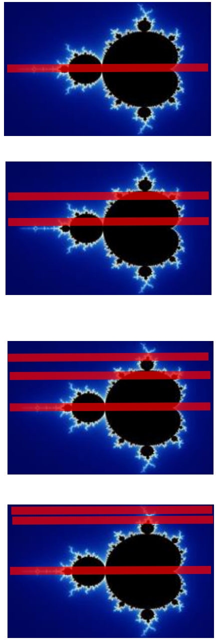
Task is a function object

Parallel algorithm

```
parallel_for( 0, max_row,
  [&](int i) {
    for (int j = 0; j < max_col; j++)
      p[i][j]=mandel(Complex(scale(i),scale(j)),depth);
  }
);
```

Use C++ lambda functions to define function object in-line

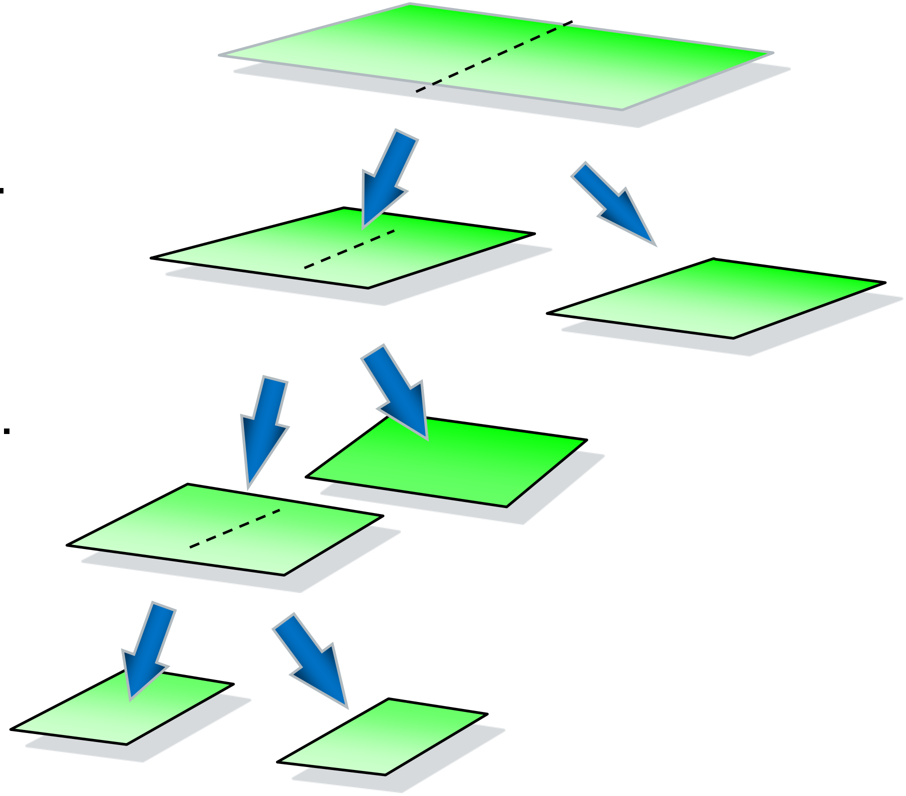
A parallel_for recursively divides the range into subranges that execute as tasks - Intel® Threading Building Blocks (Intel® TBB)



Split range...

.. recursively...

...until ≤ grainsize.



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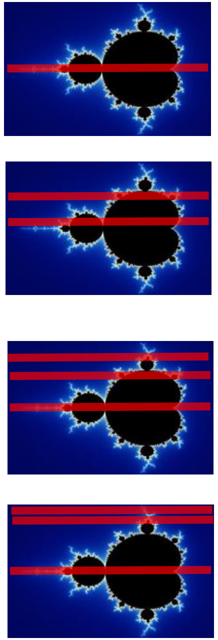

Split range...

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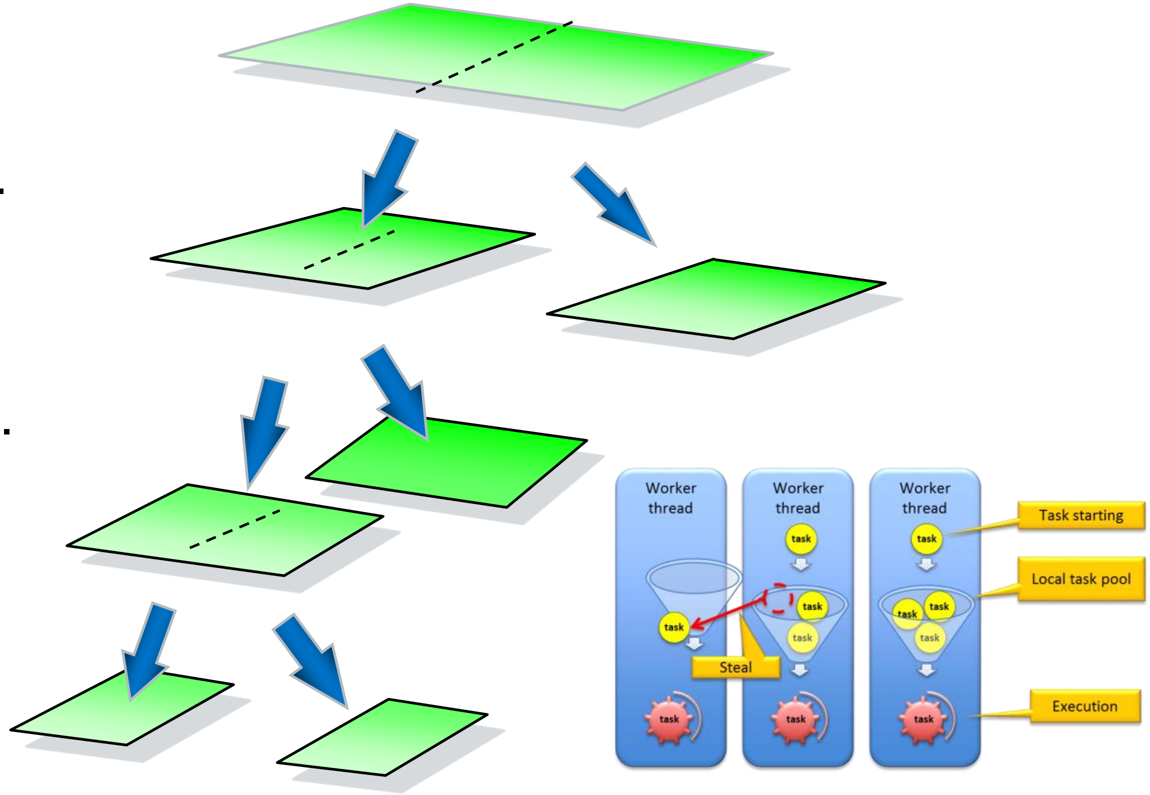
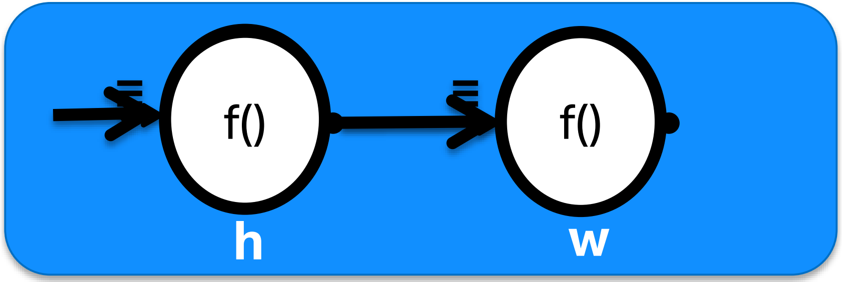


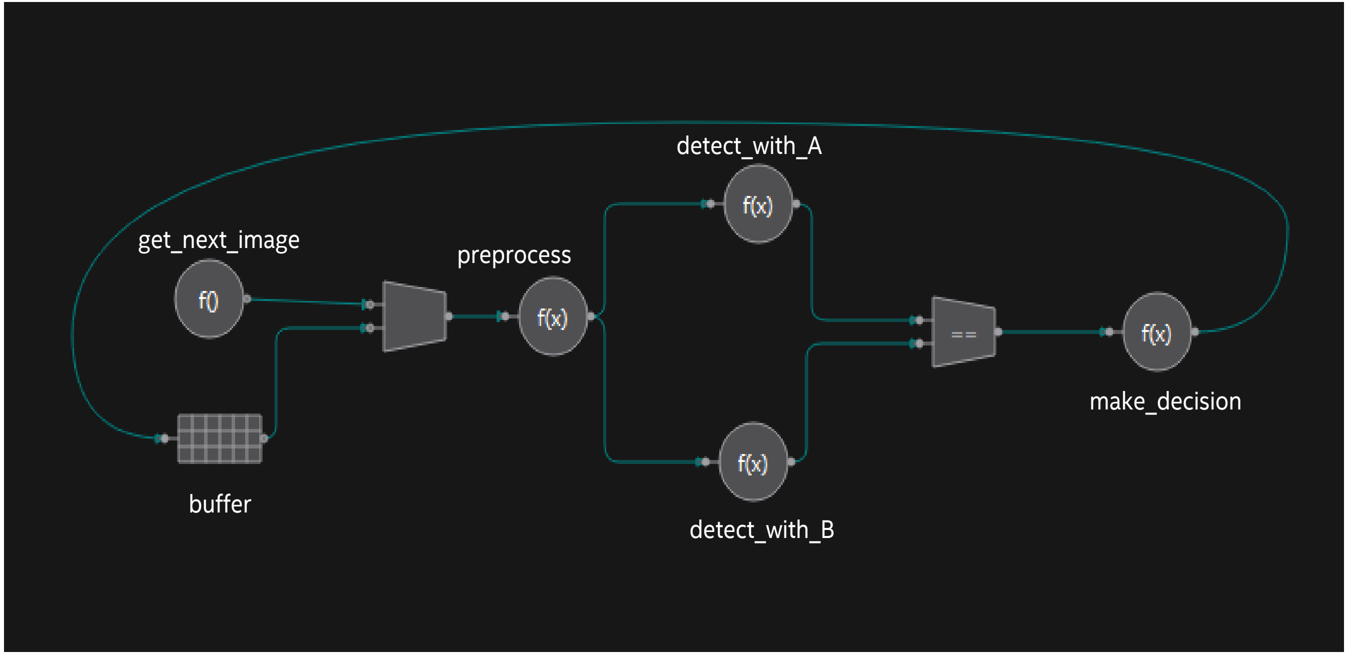
Flow Graph Hello World Example

Users create nodes and edges, interact with the graph and wait for it to complete

```
tbb::flow::graph g;

tbb::flow::continue_node< tbb::flow::continue_msg >
  h( g, []( const continue_msg & ) { std::cout << "Hello "; } );
tbb::flow::continue_node< tbb::flow::continue_msg >
  w( g, []( const continue_msg & ) { std::cout << "World\n"; } );
tbb::flow::make_edge( h, w );

h.try_put(continue_msg());

g.wait_for_all();
```

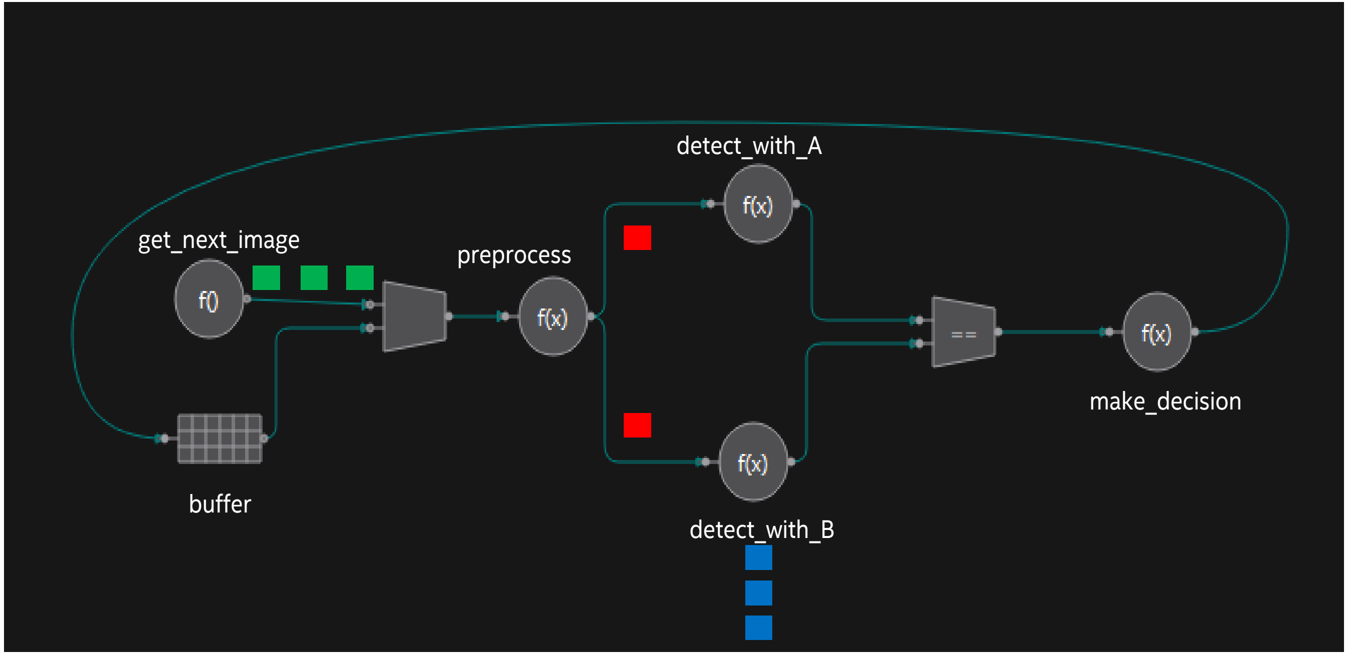


An example feature detection algorithm



Can express pipelining, task parallelism and data parallelism

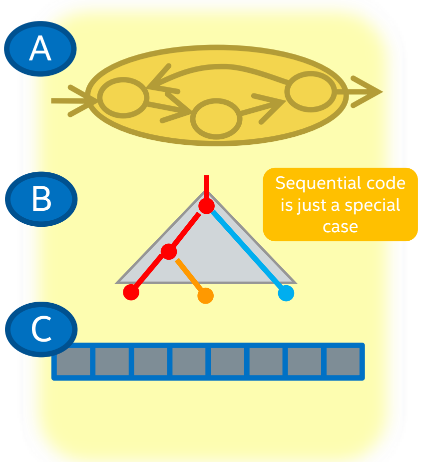
An example feature detection algorithm



Can express pipelining, task parallelism and data parallelism

And supports nested parallelism with Intel TBB, OpenMP,*
Intel® Cilk™ Plus, Intel® Math Kernel Library (Intel® MKL), etc…

CPU Programming Model Hierarchy



- Message Driven (TBB Flow Graph)
  Uses same resources/scheduler as (B) since (A) is just a another hierarchical layer
- Fork Join / Tasking (TBB Tasks)
  Tolerant of unanticipated CPU loads and support efficient composition
- SIMD
  Requires compiler support. New standardization proposal for parallel STL in C++ will integrate this layer into the same software stack.

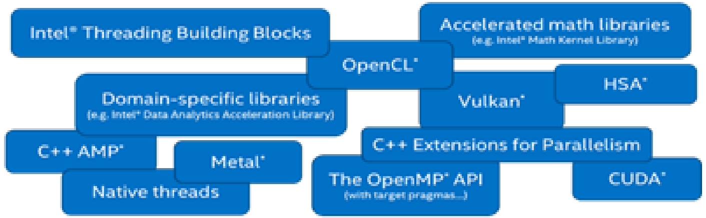
Intel® Threading Building Blocks (Intel® TBB) is the C++ library that provides what is needed for the **Message Driven** and **Fork Join / Tasking** layers

Use all your available compute resources across HW and SW through Intel TBB

Hardware
Integrated graphics, media, CPU's along with discrete co-processors & accelerators (FPGA's, fixed function devices etc)

Software
Other threading as well as domain specific libraries and API's

\+



Composability layer with Intel TBB
One threading engine under all hardware (CPU) side work

Co-ordination layer with Intel TBB flow graph
Be the glue connecting HW & SW, expose parallelism between blocks & simplify integration

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